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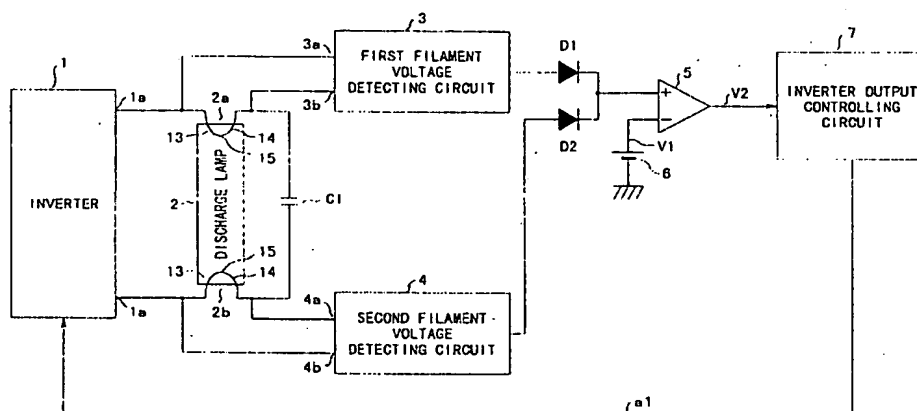
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**(54) Lighting apparatus for discharge lamps with preheating filaments**

(57) The discharge lamp lighting apparatus of the present invention includes an inverter 1 to convert input DC voltage into high frequency voltage and supply the converted high frequency voltage to a discharge lamp 2 having filaments, a preheating circuit C1 to preheat the filaments of the discharge lamp 2, a filament voltage

detecting circuit 3 to detect voltage applied between both ends of the filaments of the discharge lamp 2, and an output controlling circuit 7 to control the inverter to stop or lower the output of high frequency voltage when the detected result of the filament voltage detecting circuit 3 exceeds a specified value.

FIG. 1



## Description

The present invention relates to a discharge lamp lighting apparatus to light a discharge lamp and to a lighting apparatus using this discharge lamp lighting apparatus.

Fluorescent lamps, metal halide lamps, mercury lamps and high pressure sodium lamps, for example, have previously been sold for use as discharge lamps. Discharge lamp lighting apparatus to operate these discharge lamps are known in which a high frequency oscillation circuit generates a high frequency voltage by switching a DC voltage obtained from a rectifying means ON and OFF using a switching device in such a way that the time for which the switching device is ON is adjustable, and supplies this high frequency voltage to discharge lamps.

Discharge lamps having a small tube diameter (about 15 mm) have recently been developed. Previously, discharge lamps have had a diameter of around 30 mm. If the tube diameter of a discharge lamp is small, its starting voltage will tend to increase. Therefore, it is necessary to set the output voltage of an inverter at a high level when a discharge lamp with a small tube diameter is the load.

A discharge lamp lighting apparatus in which capacitors are connected in parallel to the discharge lamps for preheating filaments is known. In a discharge lamp lighting apparatus with capacitors connected in parallel, the preheating current becomes an almost constant current if the resistance of the filament is small. This constant current is proportional to the output voltage of the inverter.

A metallic vapor deposited film (mainly composed of tungsten with electric resistance of several hundred  $\Omega$ ) is produced between stems of a discharge lamp by spatter of filament. When the filament is burnt out, the constant current supplied from the capacitor flows through the metallic vapor deposited film and consumes electric power. Therefore, if the tube diameter is too small, flares and stems of a thin discharge lamp may melt and contact the tube wall and may crack the tube. Further, when a resin member is used for component parts of the discharge lamp, for example, electrode sockets, there is the danger that this electrode sockets might melt or be ignited. It is therefore difficult to make the tube diameter of discharge lamps too small.

In known discharge lamp lighting apparatus with capacitors connected in parallel to the discharge lamps for preheating filaments as described above, a constant current supplied from the capacitors flows in a metallic vapor deposited film formed by the spatter and consumes electric power when a filament is burned out. As a result, if a tube diameter is made too small, flares and stems of discharge lamps melt and the lamp becomes cracked when the melted flares and stems contact the tube wall. Further, when resin members are used for component parts, they can be dissolved or ignited. It is

therefore difficult to reduce the tube diameter of discharge lamps.

The present invention seeks to provide a discharge lamp lighting apparatus having a more simple circuit construction, which is capable of reducing electric power generated in a metallic vapor deposited film by the spatter when a filament is burnt out.

According to the present invention, there is provided a discharge lamp lighting apparatus, for lighting a discharge lamp having filaments, comprising an inverter for converting an input DC voltage into a high frequency voltage and for supplying the high frequency voltage to the discharge lamp filaments, characterised in that the discharge lamp lighting apparatus further comprises:

filament monitoring circuit means for monitoring the electrical characteristics of the discharge lamp; and an output control circuit for controlling the inverter in response to the output of the filament monitoring circuit means.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

FIGURE 1 is a block diagram showing a first embodiment of a discharge lamp lighting apparatus of the present invention;

FIGURE 2 is a sectional view showing a known discharge lamp;

FIGURE 3 is a circuit diagram showing a discharge lamp in which the filament has burnt out;

FIGURE 4 is a circuit diagram showing two discharge lamps connected in series to an inverter transformer as shown in FIGURE 1;

FIGURE 5 is a graph showing the relationship between a resistance value  $R_f$  and a ratio  $Wf/A$  for the arrangements shown in FIGURE 3 and FIGURE 4; FIGURE 6 is a circuit diagram showing a specific example of the discharge lamp lighting apparatus shown in FIGURE 1;

FIGURE 7 is a circuit diagram showing a capacitor mounted between adjoining stems of electrodes of the discharge lamp shown in FIGURE 3;

FIGURE 8 is a graph showing the relationship between a resistance value  $R_f$  and a ratio  $Wf/A$  for the arrangement shown in FIGURE 7;

FIGURE 9 is a circuit diagram showing impedance elements such as, for example, capacitors mounted between the adjoining stems of the discharge lamp shown in FIGURE 3;

FIGURE 10 is a block diagram showing a second embodiment of the discharge lamp lighting apparatus of the present invention;

FIGURE 11 is a block diagram showing a third embodiment of the discharge lamp lighting apparatus of the present invention; and

FIGURE 12 is a perspective view showing a lighting apparatus including the discharge lamp lighting apparatus according to the embodiments of the present invention shown in FIGURE 1 through FIGURE 11.

Hereinafter, preferred embodiments of the present invention will be described with reference to the attached drawings.

FIGURE 1 is a block diagram showing a first embodiment of the discharge lamp lighting apparatus of the present invention.

In FIGURE 1, reference numeral 1 denotes an inverter which converts input DC voltage to high frequency voltage and supplies it to a discharge lamp.

An output terminal 1a of the inverter 1 is connected to one end of a filament 15 of an electrode 2a by way of a first stem 13 of the electrode 2a of a discharge lamp 2. The other output terminal 1b of the inverter 1 is connected to one end of the filament 15 of the other electrode 2b of the discharge lamp 2 via the first stem 13 of the other electrode 2b.

A capacitor C1 is provided for preheating the filament when starting the discharge lamp, and is connected in parallel with the discharge lamp 2. When described in more detail, one of the terminals of the capacitor C1 is connected to the other end of the filament 15 of the electrodes 2a via a second stem 14 of the electrode 2a of the discharge lamp 2. The other end of the capacitor C1 is connected to the other end of the filament of the electrode 2b via the second stem 14 of the electrode 2b of the discharge lamp 2.

First and second input terminals 3a and 3b of a first filament voltage detecting circuit 3 are connected to the first and second stems 13 and 14 of the electrode 2a of the discharge lamp 2, respectively. The first filament voltage detecting circuit 3 detects voltage applied between the first and second stems 13 and 14 of the electrode 2a of the discharge lamp 2 and supplies the detected voltage to a non-inverting input terminal (+) of a comparator 5 via the anode-cathode path of a diode D1.

First and second input terminals 4a and 4b of a second filament voltage detecting circuit 4 are connected to the first and second stems 13 and 14 of the electrode 2a of the discharge lamp 2, respectively. The second filament voltage detecting circuit 4 detects voltage applied between the first and second stems 13 and 14 of the electrode 2b of the discharge lamp 2 and supplies the detected voltage to the non-inverting input terminal (+) of the comparator 5 via the anode-cathode path of a diode D2.

DC voltage V1 from a DC regulated voltage source 6 is led to an inverting input terminal (-) of the comparator 5.

When at least one of detected results of the first and second filament voltage detecting circuits 3 and 4 exceeds the DC voltage V1, the comparator 5 supplies high level (H) output voltage V2 to an inverter output

controlling circuit 7 and when the output of at least one of the first and second filament voltage detecting circuits 3 and 4 is below the DC voltage V1, the comparator 5 supplies a low level (L) output voltage V2 to the inverter output controlling circuit 7.

When the output voltage V2 of the comparator 5 is at high level (H), the inverter output controlling circuit 7 supplies a control signal a1 to the inverter 1 to stop or lower the output of the inverter 1. When the output voltage V2 of the comparator 5 is at low level (L), the inverter output controlling circuit 7 supplies a control signal a1 to the inverter 1 to carry out the normal operation.

Thus, the diodes D1 and D2, the comparator 5, the DC regulated voltage source 6, and the inverter output controlling circuit 7 comprise an output control circuit to stop or lower the output of high frequency voltage by controlling the inverter 1 if the detected results of the first and second filament voltage detecting circuits 3 and 4 are in excess of a specified value.

FIGURE 2 is a sectional view showing a discharge lamp 2.

In FIGURE 2, Reference Numeral 11 is an arc tube made of a U-shaped glass tube. Each end of this arc tube 11 is tightly closed by a flare 12. On the flare 12, the first and second stems 13 and 14 are erected at specified spaces. The filament 15 is provided between the first and second stems 13 and 14. At both ends of the arc tube 11, an electrode socket 16 is mounted. The discharge lamp 2 is connected to the discharge lamp lighting apparatus by the electrode socket 16 in the lighting apparatus. In this case, the distance between the flare top of the discharge lamp 2 and the electrode socket 16 is assumed to be A.

On the flare 12 between the first and second stems 13 and 14 of the discharge lamp 2, a metallic vapor deposited film 17 (mainly made of tungsten with electric resistance more than several hundred  $\Omega$ ) is formed by the spatter of the filament 15. When the filament 15 is burnt out, the constant-current supplied from the capacitor C1 shown in FIGURE 1 flows to the vapor deposited film 17 and consumes the electric power.

The operation of an embodiment of the present invention will be described in the following.

While the filament 15 operates normally, the preheating current from the capacitor C1 flows through the filament 15. Further, as a value of electric resistance of the filament 15 is small against the metallic vapor deposited film 17, very little current flows in the vapor deposited film 17 which is produced between the adjoining first and second stems 13 and 14. Accordingly, both of the detected results of the first and second filament voltage detecting circuits 3 and 4 are below the DC voltage V1. As a result, the output voltage V2 of the comparator 5 becomes to low level (L) and the inverter output controlling circuit 7 supplies the control signal a1 to the inverter 1 to carry out the normal operation. Thus, the inverter 1 turns the discharge lamp 2 ON in the normal state.

When the discharge lamp 2 comes to the end of its

life and the filament is burnt out, the preheating current from the capacitor C1 flows through the vapor deposited film 17 which has a relatively high resistance. Accordingly, of the voltage detected by the first and second filament voltage detecting circuits 4 and 5 at the side where the filament was burnt out is higher than the DC voltage V1. As a result, the output voltage V2 of the comparator 5 becomes high level (H) and the inverter output controlling circuit 7 supplies the control signal a1 to the inverter 1 to stop or lower its output. Thus, the inverter 1 does not supply electric power solely to the discharge lamp 2 or reduces it, thus preventing or suppressing the overheat of the stems 13 and 14 and flare 12 of the discharge lamp 2.

As described above, according to the embodiment of the present invention, the first and second filament voltage detecting circuits 3 and 4 detect voltage applied between the first and second stems 13 and 14 of the discharge lamp 2. The inverter output controlling circuit 7 controls the inverter 1 to stop or lower the output of high frequency voltage when the detected results of the first and second filament voltage detecting circuits 4 and 5 are above the specified value. As a result, the electric power consumed by a metallic vapor deposited film by the spatter when the filament is burnt-out can be reduced. Thus, the lamp crack caused by the flares and stems dissolved and contacting the tube wall is prevented even if the tube diameter of the discharge lamp is small. In addition, when a resin made member was used for component parts, it is possible to prevent this resin member being dissolved or ignited. As a result, it becomes possible to make the tube diameter of the discharge lamp small.

Hereinafter, the method for setting a specified value of the inverter output controlling circuit 7 (in case of FIGURE 1, DC voltage V1 that is used by the comparator 5) will be described with reference to FIGURE 3 through FIGURE 5.

FIGURE 3 is a circuit diagram showing the discharge lamp 2 shown in FIGURE 1, when the filament has burnt out.

In FIGURE 3, the filament of the electrode 2b at one side of the discharge lamp 2 is burnt out and a resistance value  $R_f$  of a metallic vapor deposited film between the first and second stems 13 and 14 of the electrode 2b side of the discharge lamp 2 is expressed by a variable resistor VR1. In this case, the capacitance of the capacitor C1 which is connected in parallel to the discharge lamp 2 is 10,000 pF.

FIGURE 4 is a circuit diagram showing a discharge lamp 22 with a burnt out filament connected with a discharge lamp 21 in series between the output terminals 1a and 1b of the inverter 1 shown in FIGURE 1.

In FIGURE 4, the output terminal 1a of the inverter 1 is connected to one end of the filament 15 of an electrode 21a of the discharge lamp 21 via the first stem 13 of the electrode 21a. The other output terminal 1b of the inverter 1 is connected to the first stem 13 of the other

electrode 22b of the discharge lamp 22.

The first and second stems 13 and 14 of an electrode 21b of the discharge lamp 21 are connected to the first and second stems 13 and 14 of the other electrode 22a of the discharge lamp 22, respectively.

A capacitor C2 is used for preheating when starting the discharge lamps. This capacitor C2 is connected in parallel to the in-series connected discharge lamps 21 and 22. When described in more detail, one of the terminals of the capacitor C2 is connected to the second stem 14 of the electrode 21a of the discharge lamp 21 and the other terminal of the capacitor C2 is connected to the second stem 14 of the electrode 22b of the discharge lamp 22.

The filament at the electrode 22b side of the discharge lamp 22 is burnt out and a value of resistance  $R_f$  of a metallic vapor deposited film between the first and second stems 13 and 14 at the other side is expressed by a variable resistor VR2.

In FIGURE 3 and FIGURE 4, a distance A between the flare top and the electrode socket 16 of the discharge lamp is 15 mm.

In this case, the capacitance of the capacitor C2 is 5,100 pF.

FIGURE 5 is a graph showing the relationship between a resistance value  $R_f$  of the metallic vapor deposited film and the ratio  $W/A$  between the electric power  $W$  consumed between the ends of the first and second filaments of the discharge lamps and the distance A between the flare top and the electrode socket of the discharge lamps when the inverter 1 applies normal high frequency voltage to the discharge lamps in the state shown in FIGURE 3 and FIGURE 4.

As shown in FIGURE 5, a ratio  $W/A$  between the maximum power consumed between both ends of the first and second filaments of the discharge lamps and the distance A between the flare top and the electrode socket of the discharge lamps becomes 1.1 W/mm for the arrangement shown in FIGURE 3. A ratio  $W/A$  between the maximum power consumed between both ends of the first and second filaments of the discharge lamp and the distance A between the flare top and the electrode socket of the discharge lamps becomes 2.4 W/mm for the arrangement shown in FIGURE 4. When a resin member is used for the electrode socket 16 of the discharge lamp, heat causing an abnormality of the electrode socket of the discharge lamp is generated. Because of this, a specified value of the inverter output controlling circuit 7 is set up so that a ratio between the maximum power consumed between both ends of the first and second filaments of the discharge lamps and the distance A between the top of the flare 12 and the electrode 16 of the discharge lamp becomes less than 2.4 W/mm in the embodiment of the invention shown in FIGURE 1. Thus, the distance A between the top of the flare 12 and the electrode socket 16 of the discharge lamp can be reduced to 15 mm.

Similarly, when a metallic member is used for the

electrode socket 16 of the discharge lamp, a specified value of the inverter output controlling circuit 7 is set up so that a ratio  $W/A$  becomes 4.8 W/mm. Thus, the distance  $A$  between the top of the flare 12 and the electrode socket 16 of the discharge lamp can be reduced to 15 mm.

FIGURE 6 is a circuit diagram showing a specific example of the discharge lamp lighting apparatus shown in FIGURE 1.

In FIGURE 6, one of the output terminals of a commercial AC power source 31 is connected to an input terminal P1 of the discharge lamp lighting apparatus and the other terminal is connected to an input terminal P2 of the discharge lamp lighting apparatus.

The input terminal P1 is connected to one end of a capacitor C11 and one end of a primary winding L11 of a transformer 32 and the input terminal P2 is connected to one end of the capacitor C11 for removing high frequency and one end of a secondary winding L12 of the transformer 32. As a result of such connections, ripple of AC supply voltage from the commercial AC power source is removed by the capacitor C11 and the transformer 32 and AC supply voltage is obtained between the other end of the primary winding L11 and that of the secondary winding L12. The other end of the primary winding L11 of the transformer 32 is connected to one of the input terminals of a rectifier circuit 33. The other end of the secondary winding L12 of the transformer 32 is connected to the other input terminal of the rectifier circuit 33. Between the input terminals of the rectifier circuit 33, a capacitor C12 is connected.

AC supply voltage generated between the other end of the primary winding L11 and that of the secondary winding L12 is rectified by the rectifier circuit 33 and converted to non-smoothed DC supply voltage.

The positive pole side output terminal of the rectifier circuit 33 is connected to the positive pole side input terminal of an inverter 40. The negative pole side output terminal of the rectifier circuit 33 is connected to the negative pole side input terminal of the inverter 40.

The inverter 40 is composed of a first switching means 41, e.g., MOSFET, a second switching means 42, e.g., MOSFET, driver circuits 43 and 44 for driving the first and second switching means 41 and 42, a driver control circuit 45, a start-up circuit 46, power supply variation control circuits 47 and 48 for controlling the power supply variation of the first and second switching means 41 and 42, a preheat time control power supply circuit 49, a reset circuit 50 for resetting this preheat time control power supply circuit 49, a winding L21 of a super saturation current transformer CT1, resistors R21 and R22, a diode D21, capacitors C21, C22 and C23, an electrolytic capacitor C24, and windings L14 and L15 of a high frequency transformer T1.

One of the output terminals of the inverter 40 is connected to a terminal P11 of a socket 51. A terminal P11 of the socket 51 is connected to one end of the filament of one of the electrodes of a discharge lamp 60 via a

first stem of the other electrode of the discharge lamp 60. The other output terminal of the inverter 40 is connected to a terminal P13 of a socket 52 via an in-series connected inductance L51 and a DC removing capacitor C51. The terminal P13 of the socket 52 is connected to one end of the filament of the other electrode of the discharge lamp 60 via the first stem of the other electrode.

The capacitor 52 is for preheating and resonating when starting up the discharge lamp and is connected to the discharge lamp 60 in parallel. When described in more detail, one of the terminals of the capacitor 52 is connected to a terminal P12 of the socket 51. This terminal P12 of the socket 51 is connected to the other end of the filament of one of the electrodes of the discharge lamp 60 via the second stem of the other electrode. The other end of the capacitor C52 is connected to a terminal P14 of the socket 52. The terminal P14 of the socket 52 is connected to the other end of the filament of the other electrode via the second stem of the other electrode of the discharge lamp 60.

First and second input terminals of a first filament voltage detecting circuit 53 are connected to the terminals P11 and P12 of the socket 51, respectively. The first filament voltage detecting circuit 53 detects voltage applied between both ends of the first and second filaments of one of the electrodes of the discharge lamp 60 and transmits the detected voltage to an output control circuit 56 by a photocoupler PC1.

First and second input terminals of a second filament voltage detecting circuit 54 are connected to the terminals P13 and P14 of the socket 52, respectively. The second filament voltage detecting circuit 54 detects voltage applied between both ends of the first and second filaments of one of the electrodes of the discharge lamp 60 and transmits the detected voltage to the output control circuit 56 by a photocoupler PC2.

First and second input terminals of a lamp voltage detecting circuit 55 are connected to the terminal P11 of the socket 51 and the terminal P13 of the socket 52, respectively. The lamp voltage detecting circuit 55 detects voltage applied between both electrodes of the discharge lamp 60 and transmits this detected voltage to the driver control circuit 45 and the output control circuit 56 by photocouplers PC3 and PC4, respectively.

A driver circuit 43 is composed of a winding L22 of the super saturation current transformer CT1 and resistors R31 and R32.

A driver circuit 44 is composed of a winding L23 of the super saturation current transformer CT1 and resistors R33 and R34.

The driver control circuit 45 is composed of Zener diodes ZD1, ZD2 and ZD3, a phototransistor of the photocoupler PC3 and a transistor Tr1.

The start-up circuit 46 is composed of a trigger diode D10 and a resistor R35.

The power supply variation control circuit 47 is composed of resistors, R41, R42, R43, R44, R45 and R46, diodes D41 and D42, a capacitor C41, an electrolytic

capacitor C42, and transistors Tr41, Tr42 and Tr43.

The power supply variation control circuit 48 is composed of resistors R48, R49, R50, R51 and R52, diodes D43 and D44, electrolytic capacitors C43, C44 and C45, transistors Tr44 and Tr45 and Zener diode ZD41.

The preheat time control power supply circuit 49 is composed of resistors R61 and R62, capacitors C61 and C62, transistor Tr61 and Zener diode ZD61.

The reset circuit 50 is composed of resistors R63 and R64, a capacitor C63 and a transistor Tr62.

The first filament voltage detecting circuit 53 is composed of a resistor R71, capacitors C71 and C72, diodes D71 and D72, a Zener diode ZD71 and a light emitting diode of the photocoupler PC1.

The second filament voltage detecting circuit 54 is composed of a resistor R72, capacitors C73 and C74, diodes D73 and D74, a Zener diode ZD72 and a light emitting diode of the photocoupler PC2.

The lamp voltage detecting circuit 55 is composed of a resistor R73, a capacitor C76, an electrolytic capacitor C77, diodes D75, D76 and D77, light emitting diodes of the photocouplers PC3 and PC4, and a transistor Tr71.

The output control circuit 56 is composed of resistors R81, R82, R83, R84, R85 and R86, capacitors C81 and C82, an electrolytic capacitor C83, a diode D81, a Zener diode ZD81, phototransistors of photocouplers PC1, PC2 and PC4, a transistor Tr81, a MOSFET 57 and a thyristor SCR1.

A specific example of the operation of the discharge lamp lighting apparatus in the construction as shown above will be described in the following.

When the discharge lamp 60 is in the normal state, the photodiodes of the photocouplers PC1 and PC2 of the first and second filament voltage detecting circuits 53 and 54 are in the OFF state. As a result, in the output control circuit 56, the phototransistors of the photocouplers PC1 and PC2 are in the OFF state and the transistor Tr81 is in the ON state and the MOSFET 57 is in the OFF state. Therefore, as no current flows to the output control circuit 56 from the connecting point of the resistor R33 of the driver circuit 44 and the winding L23 of the super saturation current transformer CT1, the switching means 41 and 42 maintain the normal oscillation and the discharge lamp 60 maintains the normal lighting state.

When the filament of at least one of the electrodes of the discharge lamp 60 is burnt out, at least one of the photodiodes of the photocouplers PC1 and PC2 of the first and second filament voltage detecting circuits 53 and 54 is turned ON. As a result, in the output control circuit 56, at least one of the phototransistors of the photocouplers PC1 and PC2 is turned ON, the transistor Tr81 is turned OFF and the MOSFET 57 is turned ON. Therefore, the current flows to the output control circuit 56 from the connecting point of the resistor R33 of the driver circuit 44 and the winding L23 of the super saturation current transformer CT1, the switching means 41

and 42 stop the oscillation and the discharge lamp 60 is put out.

As shown in such this specific example, the embodiment of the present invention shown in FIGURE 1 can be realized.

Hereinafter, an arrangement in which an impedance element is mounted between the ends of the first and second filaments in parallel in the embodiment shown in FIGURE 1 through FIGURE 5 will be described.

FIGURE 7 is a circuit diagram showing an arrangement in which a capacitor is mounted between both ends of the first and second filaments of one of the electrodes of the discharge lamp shown in FIGURE 4.

In FIGURE 7, a capacitor C101 is connected to a variable resistor VR2 in parallel.

A distance A between the flare top and the electrode socket of a discharge lamp 22 is 15 mm. Further, the capacitance of the capacitor C2 is 5,100 pF.

FIGURE 8 is a graph showing the relationship between a resistance value R1 of the metallic vapor deposited film when the inverter applies ordinary high frequency voltage to the discharge lamp as shown in FIGURE 7 and a ratio  $W/A$  of the electric power  $W$  consumed between the ends of the first and second filaments of the discharge lamp with a distance between the flare top and the electrode socket of the discharge lamp.

As shown in FIGURE 8, in the arrangement shown in FIGURE 4, that is, without the capacitor C101 provided, a ratio  $W/A$  of the maximum power consumed between both ends of the filaments of the discharge lamp and a distance A between the flare top and the electrode socket of the discharge lamp was 2.4 W/mm.

On the other hand, when the capacitance of the capacitor C101 is 5,100 pF in the state shown in FIGURE 7, a ratio  $W/A$  at the maximum power consumption becomes 1.1 W/mm. Further, when the capacitance of the capacitor C101 is 10,000 pF, a ratio  $W/A$  at the maximum power consumption becomes 0.7 W/mm.

As shown in FIGURE 8, when a capacitor is mounted between the ends of the first and second filaments of the discharge lamp, it becomes possible to further reduce electric power generated in the metallic vapor deposited film by the spatter when the filament is burnt out. Accordingly, it becomes possible to make the tube diameter of the discharge lamp smaller.

FIGURE 9 is a circuit diagram showing an arrangement in which an impedance element, such as a capacitor, is mounted between the ends of the adjoining first and second filaments of the electrode at the side to which preheating current flows via the capacitor C1 in the discharge lamp shown in FIGURE 3.

In FIGURE 9, impedance elements 102 and 103 are connected between the first and second stems 13 and 14 of the electrodes 2a and 2b of the discharge lamp 2, respectively.

Assuming that the frequency of high frequency voltage supplied to the discharge lamp 2 is  $f$ , the impedance

of the impedance element 102 is Z, the capacity of the capacitor C1 is Cf, the voltage (lamp voltage) applied between the electrodes 2a and 2b of the discharge lamp 2 is VL and the resistance (resistance of the metallic vapor deposited film) of the variable resistor VR1 is Rf, the electric power W1 that is consumed in the metallic vapor deposited film in the state shown in FIGURE 9 can be expressed by the following equation (1).

$$W1 = \left( \frac{2\pi f \times Cf \times VL \times Z}{Rf + Z} \right)^2 Rf \quad (1)$$

The electric power W2 that is consumed on the metallic vapor deposited film in the state shown in FIGURE 4 can be expressed by the following equation (2)

$$W2 = (2\pi f \times Cf \times VL)^2 \times Rf \quad (2)$$

As W1 is surely less than W2 ( $W1 < W2$ ) from Equations (1) and (2), when the impedance elements 102 and 103 are provided, it is possible to confirm that power consumed on the metallic vapor deposited film can be further reduced. Further, capacitor, coil, transformer, diode and combinations thereof are applicable for the impedance elements 102 and 103.

FIGURE 10 is a block diagram showing a second embodiment of the discharge lamp lighting apparatus of the present invention and the same reference numerals as those shown in FIGURE 1 are assigned to the same component elements and the explanation thereof is omitted.

A filament preheating circuit 111, corresponding to the capacitor C1 shown in FIGURE 1, has a first terminal 111a connected to the first stem 13 of the electrode 2a of the discharge lamp 2 and a second terminal 111b connected to the second stem 14 of the electrode 2a of the discharge lamp 2 via a primary winding L91 of a current transformer CT111. A third terminal 111c of the filament preheating circuit 111 is connected to the first stem 13 of the electrode 2b of the discharge lamp 2 and a fourth terminal 111d is connected to the second stem 14 of the electrode 2b of the discharge lamp 2 via a primary winding L93 of a current transformer CT112.

Both ends of a secondary winding L92 of the current transformer CT111 are connected to a filament current detecting circuit 113. The filament current detecting circuit 113 detects the current flowing to the filament of the electrode 2a of the discharge lamp 2 by detecting the voltage of the secondary winding L92 and converting the detected current into voltage, and supplies it to one of the input terminals of a multiplier 115. The detected voltage from the first filament voltage detecting circuit 3 is applied to the other input terminal of the multiplier 115.

The multiplier 115 multiplies the detected result of the first filament voltage detecting circuit 3 by the detected result of the filament current detecting circuit 113

and supplies the voltage result of this computation to the non-inverting input terminal (+) of the comparator 5 via the anode-cathode path of the diode D1.

Both ends of a secondary winding L94 of the current transformer CT112 are connected to a filament current detecting circuit 114. The filament current detecting circuit 114 detects the current flowing to the electrode 2b of the discharge lamp 2 by detecting the voltage of the secondary winding L94 and converting the detected current into voltage, and supplies it to one of the input terminals of a multiplier 116. The detected voltage from the second filament voltage detecting circuit 4 is led to the other input terminal of the multiplier 116.

The multiplier 116 multiplies the detected result of the filament voltage detecting circuit 4 by the detected result of the filament current detecting circuit 114 and supplies the voltage result of this computation to the non-inverting input terminal (+) of the comparator 5 via the anode-cathode path of the diode D2.

DC voltage V11 from a DC regulated voltage source 126 is applied to the inversion input terminal (-) of the comparator 5.

When at least one of the results of computation by the multipliers 115 and 116 exceeds the DC voltage V11, the comparator 5 supplies a high level (H) output voltage V2 to the inverter output controlling circuit 7. Otherwise, the comparator 5 supplies a low level (L) output voltage V2 to the inverter output controlling circuit 7.

As a result, the multiplier 115, the filament voltage detecting circuit 3 and the filament current detecting circuit 113 comprise a filament power detecting circuit to detect electric power consumed by the electrode 2a of the discharge lamp 2. The multiplier 116, the filament voltage detecting circuit 4 and the filament current detecting circuit 114 comprise a filament power detecting circuit to detect electric power consumed by the electrode 2b of the discharge lamp 2. The diodes D1 and D2, the comparator 5, the DC regulated voltage source 126 and the inverter output controlling circuit 7 comprise an output control circuit to stop or lower the output of high frequency voltage by controlling the inverter 1 when the result of computation of either of these filament power detecting circuits exceeds a specified value.

As described above, according to the second embodiment of the present invention, it is possible to obtain the same effect as that in the first embodiment of the present invention and properly control the output of high frequency voltage by accurately detecting electric power consumed by the metallic vapor deposited film.

FIGURE 11 is a block diagram showing a third embodiment of the discharge lamp lighting apparatus of the present invention, and the same reference numerals shown in FIGURE 10 are assigned to the same component elements as those in FIGURE 10 and the explanation thereof is omitted.

In the third embodiment of the present invention, a starting mode disable circuit 131 is provided to disable the inverter output controlling circuit 7 in the starting

mode.

The starting mode disable circuit 131 ensures that the non-inverting input terminal (+) of the comparator 5 is set at the low level in the starting mode.

According to the third embodiment of this invention, it is possible to prevent the output of high frequency voltage from being stopped or lowered by erroneously controlling the inverter 1 in the starting mode.

Further, in the embodiments shown in FIGURE 1 through FIGURE 11, when the inverter output controlling circuit 7 stopped or lowered the output of high frequency voltage by controlling the inverter 1, if the circuit is constructed so as to latch this state, it is possible to prevent the output of the inverter 1 rising again when the filament of the discharge lamp is burnt out in order to save power. Further, in the embodiments shown in FIGURE 1 through FIGURE 11, the capacitor for preheating the filament is provided outside the inverter but a preheating capacitor may be provided in the inverter.

FIGURE 12 is a perspective view showing a lighting apparatus applied with the discharge lamp lighting apparatus of the embodiment shown in figure 1 through FIGURE 11.

In FIGURE 12, a lighting apparatus 301 mounts discharge lamps 305 and 306 in sockets 303 and 304 of the main body of the lighting apparatus and houses the discharge lamp lighting apparatus 307 in the inside. The discharge lamps 305 and 306 are controlled by the discharge lamp lighting apparatus 307.

The embodiments of the present invention shown in FIGURE 1 through FIGURE 11 in the construction as described above can be applied to a lighting apparatus.

According to the present invention, it is possible to reduce electric power generated on the metallic vapor deposited film by the spatter when the filament is burnt out. As a result, even when the tube diameter of a discharge lamp is small, the lamp crack caused when the flares and stems are dissolved and contact the tube wall is prevented. Further, when resin made component parts are used, it is possible to prevent melting and ignition of this resin made parts and it becomes possible to make the tube diameter of the discharge lamp small.

#### Claims

1. A discharge lamp lighting apparatus, for lighting a discharge lamp (2) having filaments (15), comprising an inverter (1) for converting an input DC voltage into a high frequency voltage and for supplying the high frequency voltage to the discharge lamp filaments (15), characterised in that the discharge lamp lighting apparatus further comprises:

filament monitoring circuit means (3, 4, 113, 114) for monitoring the electrical characteristics of the discharge lamp (2); and  
an output control circuit (5, 7) for controlling the

inverter (1) in response to the output of the filament monitoring circuit means (3, 4, 113, 114).

2. A discharge lamp lighting apparatus as claimed in claim 1, wherein the filament monitoring circuit means (3, 4, 113, 114) detects a value related to the power consumed by the filaments (15) of the discharge lamp (2), and the output control circuit (5, 7) controls the inverter (1) to stop or to lower the output of high frequency voltage when the detected result exceeds a specified value.
3. A discharge lamp lighting apparatus as claimed in claim 2, wherein the filament monitoring circuit means (3, 4, 113, 114) comprises filament voltage detecting circuits (3, 4) for detecting the voltage applied between the ends of the filaments (15) of the discharge lamp (2).
4. A discharge lamp lighting apparatus as claimed in claim 2, wherein the filament monitoring circuit means (3, 4, 113, 114) comprises:  
filament voltage detecting circuits (3, 4) for detecting voltage applied between the ends of the filaments (15) of the discharge lamp (2);  
filament current detecting circuits (113, 114) for detecting current flowing to the filaments (15) of the discharge lamp (2);  
multipliers (115, 116) for multiplying the detected result of the filament voltage detecting circuit (3, 4) by the detected result of the respective filament current detecting circuit (113, 114).
5. A discharge lamp lighting apparatus as claimed in any preceding claim further comprising preheating means (C1, 111) for preheating the filaments (15) of the discharge lamp (2).
6. The discharge lamp lighting apparatus as claimed in claim 5, wherein the preheating means includes a capacitor (21) connected to the discharge lamps in parallel.

7. The discharge lamp lighting apparatus as claimed in one of claims 2-6, wherein the discharge lamp (2) includes an arc tube (11) having two ends and flares (13, 14) provided at both ends of the arc tube (11) for mounting the filaments (15), and the discharge lamp lighting apparatus has electrode sockets formed with resin to which both ends of the arc tube (11) are mounted, and the output control circuit (5, 7) sets a specified value so that a ratio between the maximum electric power consumed by the filaments when the discharge lamp is lighted and a distance between the flare top and the electrode socket becomes less than 2.4 W/mm.



8. The discharge lamp lighting apparatus as claimed in one of claims 2-6, wherein the discharge lamp (2) includes an arc tube (11) having two ends and flares (13, 14) provided at both ends of the arc tube (11) for mounting the filaments (15), and the discharge lamp lighting apparatus has further electrode sockets formed with metal to which both ends of the arc tube (11) are mounted, and the output control circuit (5, 7) sets a specified value so that a ratio between the maximum electric power consumed by the filaments when the discharge lamp is lighted and a distance between the flare top and the electrode socket becomes less than 4.8 W/mm. 5 10
9. The discharge lamp lighting apparatus as claimed in any preceding claim, further comprising an impedance element (2) connected in parallel with the filament (15) of the discharge lamp. 15
10. The discharge lamp lighting apparatus as claimed in claim 9, wherein the impedance element includes a capacitor. 20
11. The discharge lamp lighting apparatus claimed in any preceding claim further comprising a circuit (131) for disabling the output control circuit (7) in the starting mode. 25
12. The discharge lamp lighting apparatus claimed in any preceding claim, further comprising means for latching a state wherein the output control circuit (5,7) controls the inverter (2) to stop or lower the output of high frequency voltage. 30
13. A lighting apparatus (301) comprising the discharge lamp lighting apparatus (307) as claimed in any preceding claim and a main body (302) to house the discharge lamp lighting apparatus (302). 35 40 45 50 55

FIG. 1

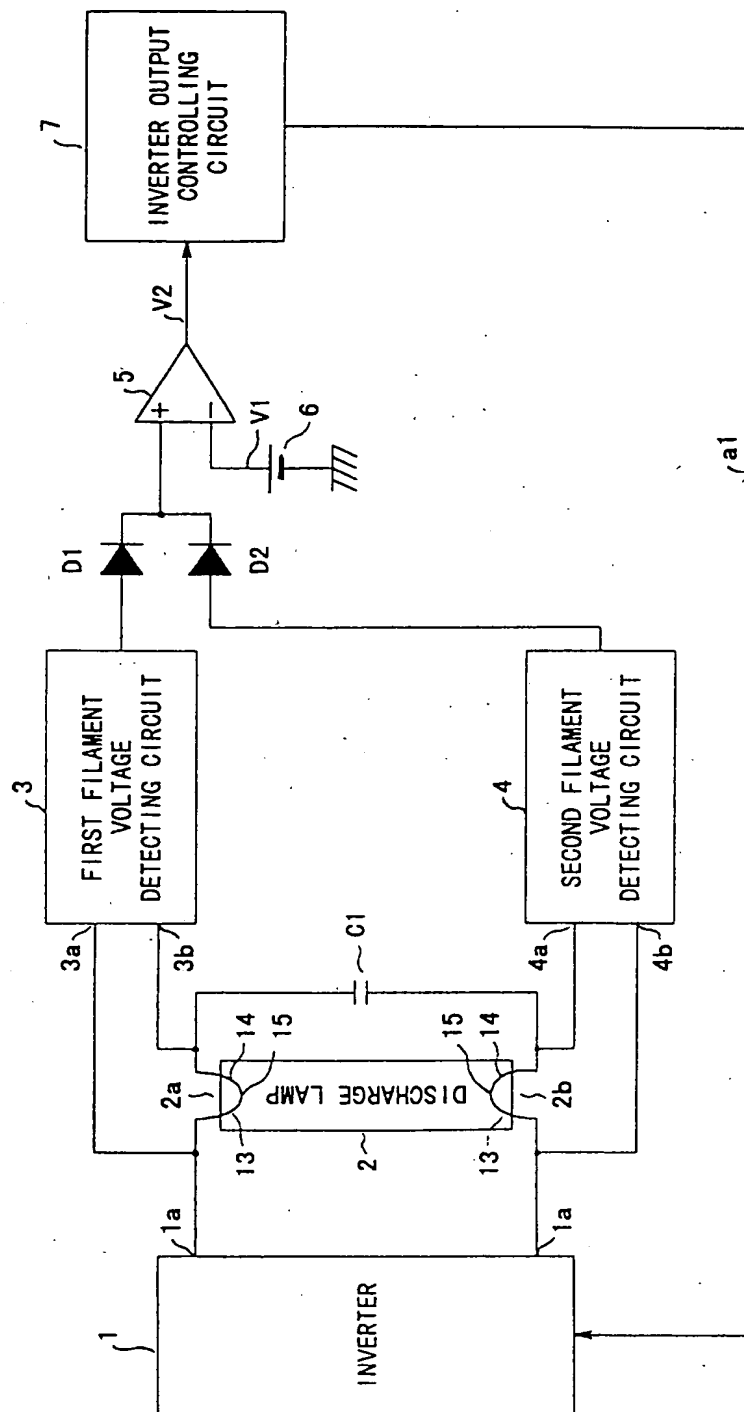




FIG. 4

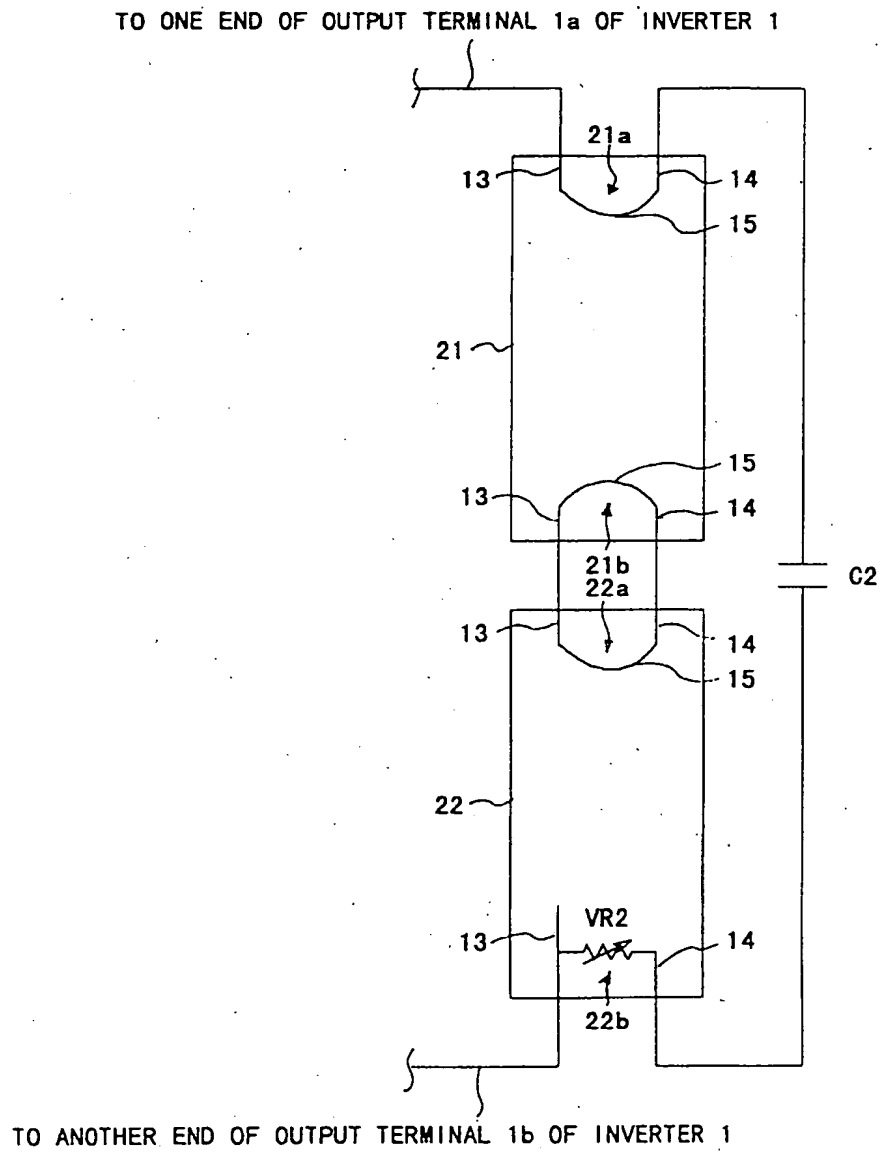


FIG. 5

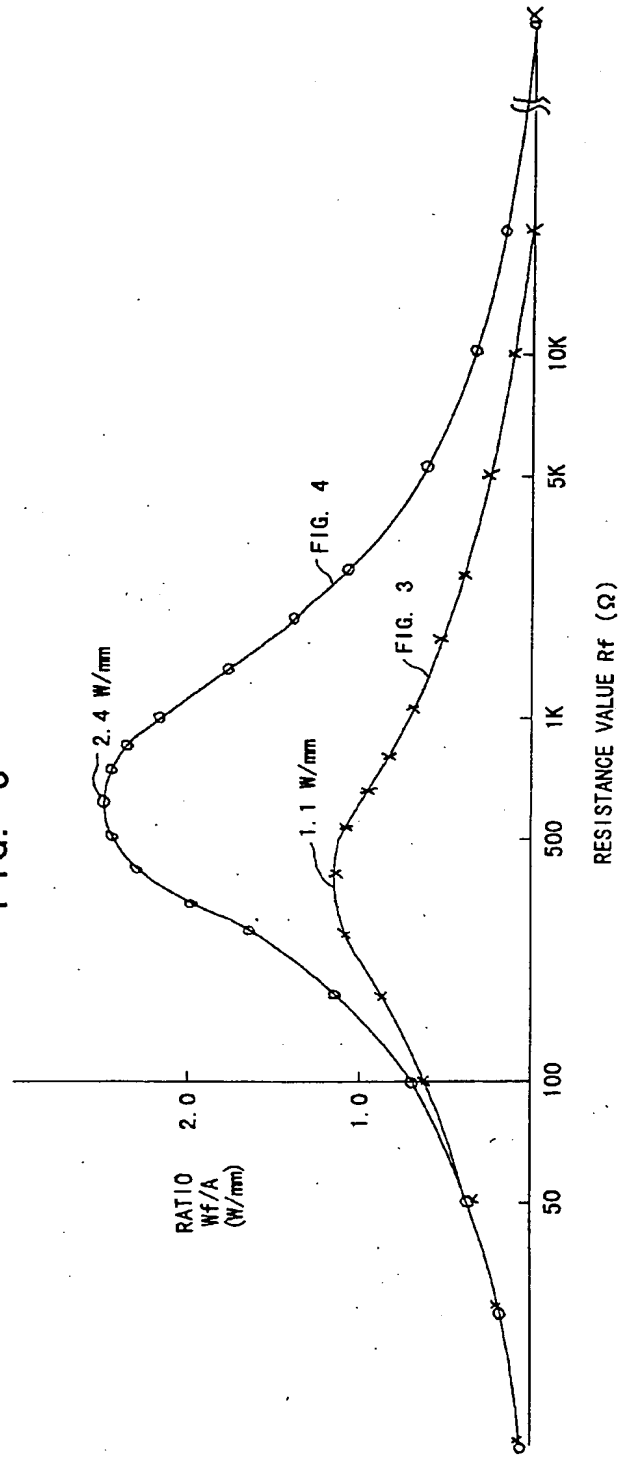


FIG. 6

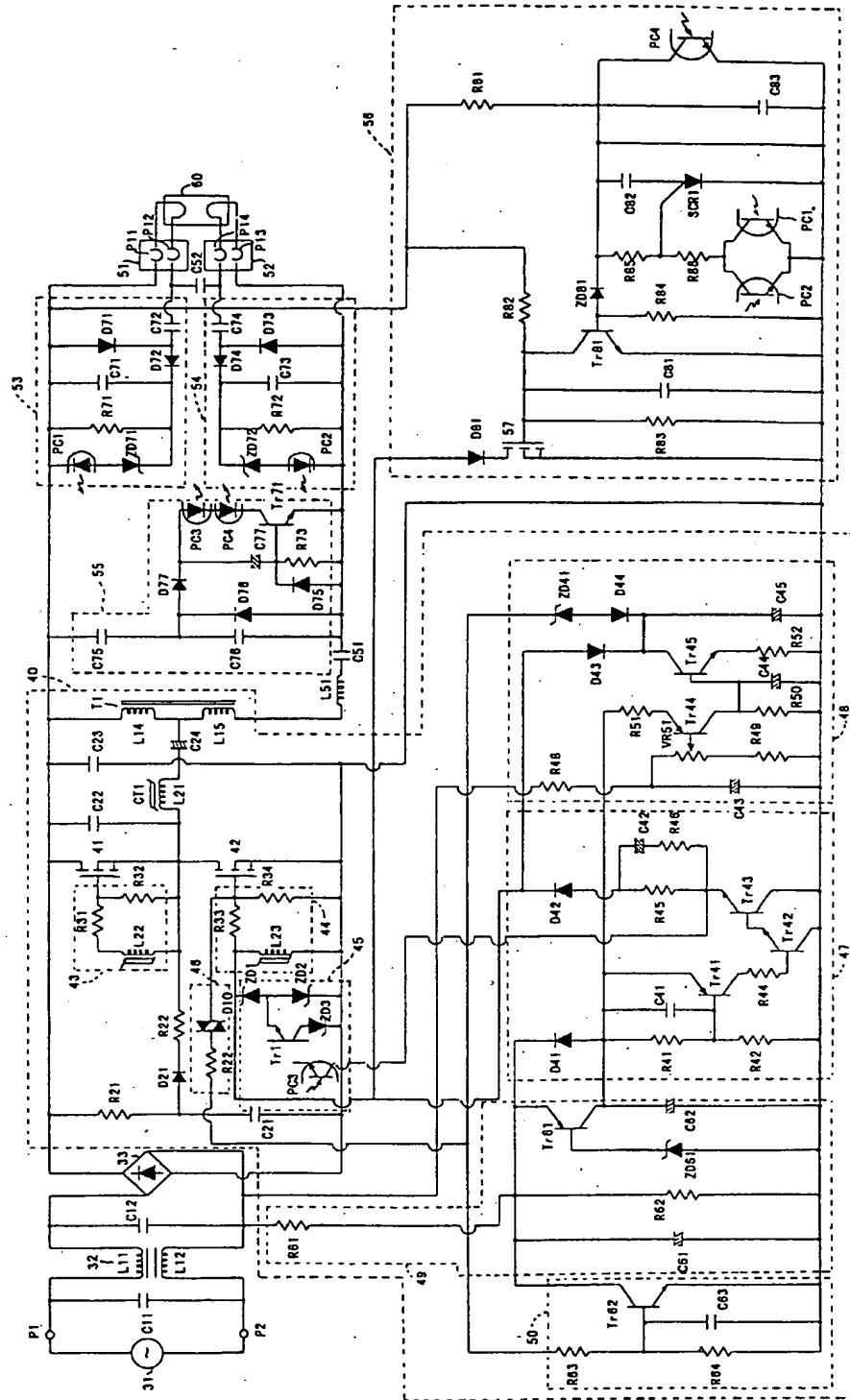


FIG. 7

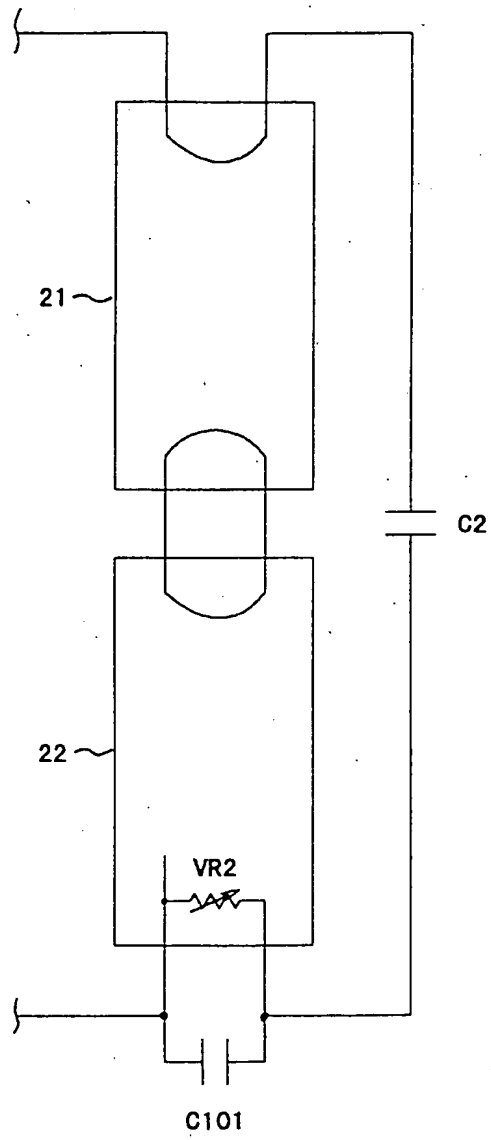


FIG. 8

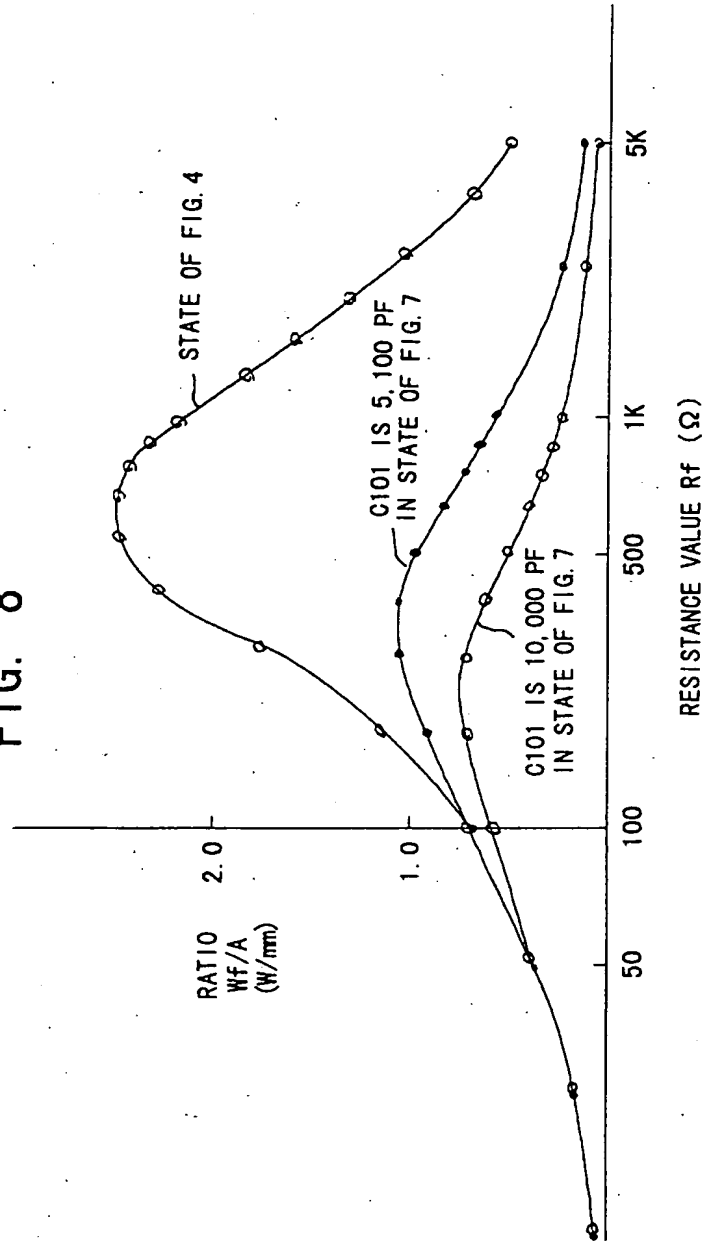




FIG. 9

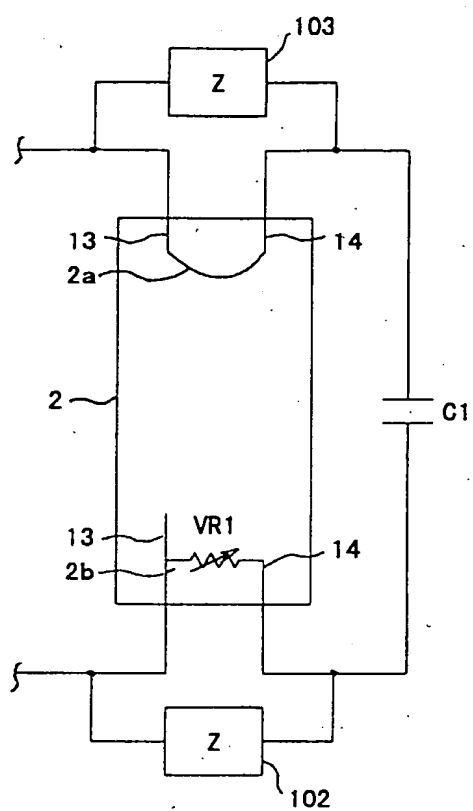


FIG. 10

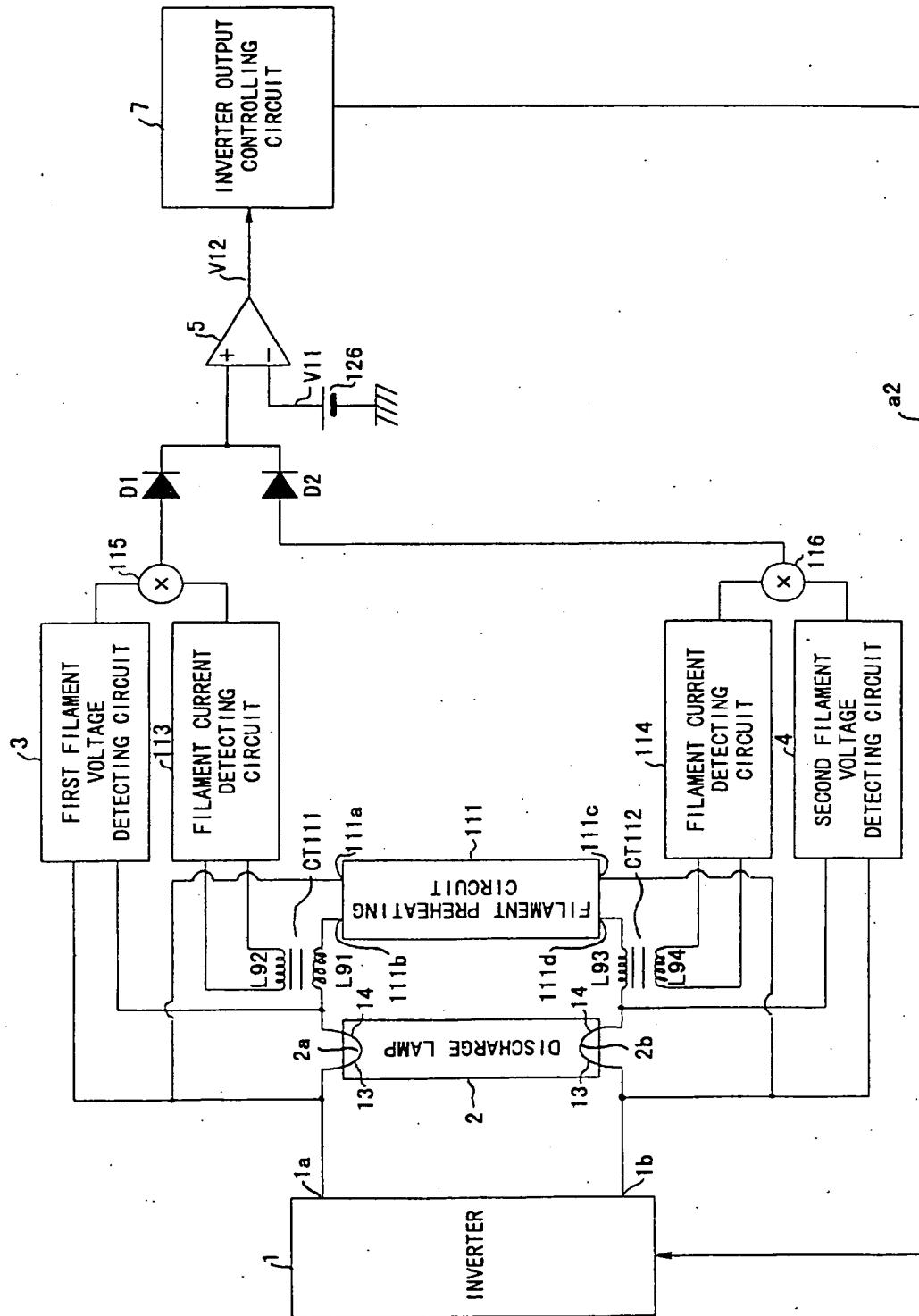


FIG. 11

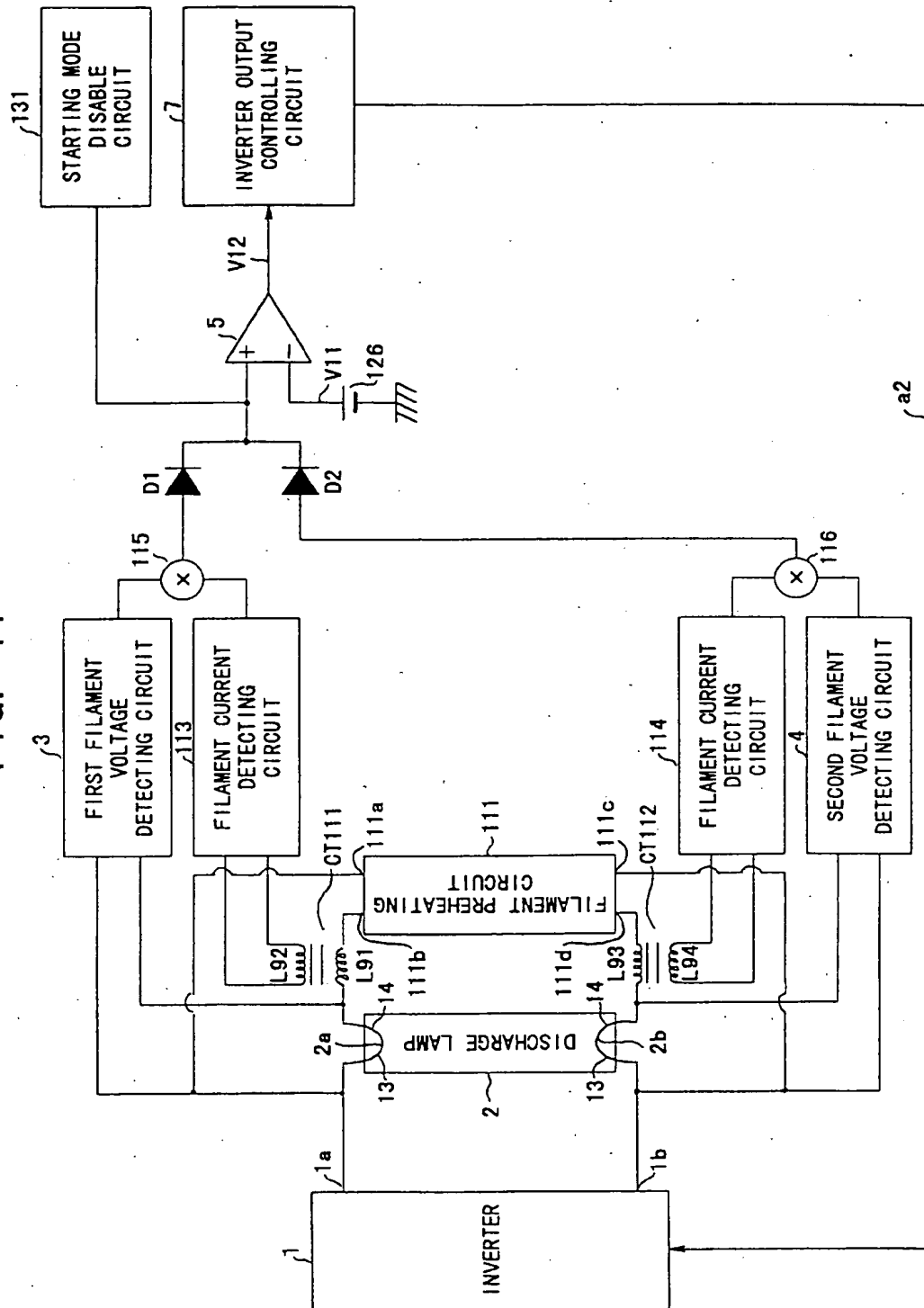
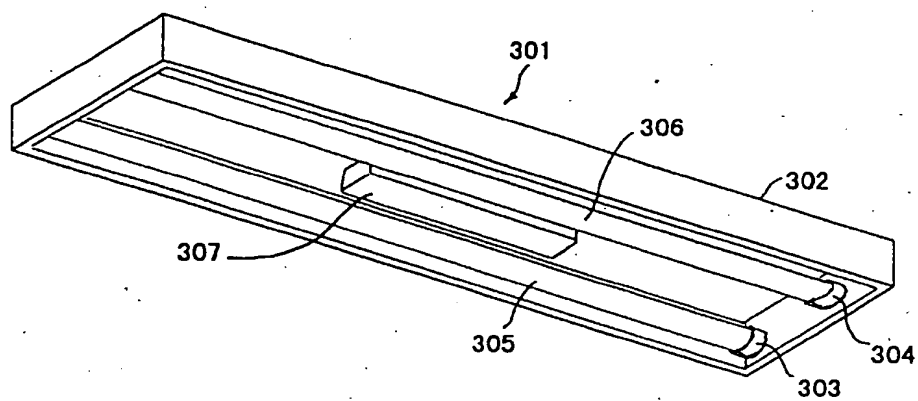


FIG. 12



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 97 30 9630

| DOCUMENTS CONSIDERED TO BE RELEVANT  |  |  |   |
|--|--|--|---|
| Category   | Citation of document with indication, where appropriate, of relevant passages  | Relevant to claim                                    | CLASSIFICATION OF THE APPLICATION (Int.Cl.6)    |
| X  | US 5 424 611 A (MORIARTY JR JOHN K)<br>* column 4, line 64 - column 5, line 15 *<br>* column 7, line 4 - column 8, line 27;<br>figures 1,4 * | 1-3,5,6  | H05B41/29                                       |
| X  | EP 0 594 880 A (KNOBEL LICHTTECH)<br>* column 3, line 47 - column 4, line 56;<br>figures 1-5 *   | 1-3  |   |
| X  | EP 0 471 332 A (DIEHL GMBH & CO)<br>* column 5, line 3 - column 6, line 5;<br>figure 1 *   | 1  |   |
| A  | DE 41 00 349 A (SIEMENS AG)<br>* column 5, line 13 - column 5, line 24;<br>figure 8 *  | 2  |   |
| A  | EP 0 338 109 A (ZUMTOBEL AG)<br>* column 7, line 43 - column 8, line 4;<br>figure 1 *  | 2  |   |
| A  | DE 43 03 624 A (EGBERTS GERHARD DR ING)<br>* figure 2 *  | 7,8  | TECHNICAL FIELDS<br>SEARCHED (Int.Cl.6)<br>H05B |
| A  | DE 43 03 595 A (PATRA PATENT TREUHAND)<br>* figures 1,3,4 *  | 9,10   |   |
| The present search report has been drawn up for all claims.  |  |  |   |
| Place of search<br>THE HAGUE   |  | Date of completion of the search<br>13 February 1998 | Examiner<br>Speiser, P                          |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |  |  |   |

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